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BUS RAPID TRANSIT-ORIENTED DEVELOPMENT: AN IDENTIFICATION OF BUS RAPID TRANSIT SYSTEM PASSENGERS' MODAL SHIFT POTENTIAL CONSIDERATIONS

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ABSTRACT

This article explores some issues that are potentially considered by bus rapid transit (BRT) system passengers when shifting their mode of transport from driving their vehicle to taking the BRT system for the same kind of trip. The issues are explored as part of an attempt to design an appropriate BRT passengers' modal shift evaluation. The BRT passengers' modal shift evaluation is to be carried out to understand how a BRT system may influence urban development around the system and how it may trigger transit-oriented development (TOD) around the system. This article was written through a literature review directed on certain topics, that are BRT ridership-influencing factors, the BRT system passengers' behavior, the built environment condition around BRT systems, the types of transit system passengers and the types of trips carried out utilizing a transit system. It is found that several components of BRT system service quality and several components of the built environment around the system potentially influence the BRT system passengers' consideration when shifting their mode of transport. However, the influence may not be homogenous among all passenger-trips due to the different passengers' backgrounds and the different types of trips carried out utilizing the BRT system.

Keywords: Bus rapid transit; consideration; modal shift; passengers; transit-oriented development

1. INTRODUCTION

Bus rapid transit (BRT) and transit-oriented development (TOD) are two concepts that are frequently discussed lately. In short, bus rapid transit is an enhanced bus service having a level of service in par with rail-based transit while having capital and operational cost lower than rail-based transit (Prayogi, 2018). Transit-oriented development is generally understood as a type of urban development triggered by and relying upon the operation of one or more rapid transit systems (Prayogi, 2018). BRT has been limitedly recognized compatible to be built in conjunction with TOD. Suzuki et al., (2013) have shown some cases where the operation of BRT systems triggered TODs around the systems.

There hasn't been much explanation on how a BRT system trigger TOD around the system. In an attempt to understand how a BRT system may trigger TOD around the system, some approaches on evaluating the influence of a BRT system towards urban development around the system have been recognized (Suzuki et al., 2013; Prayogi, 2018).

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One of the commonly practiced approaches is to evaluate the influence of a BRT system on property value around the system. This approach suggests evaluating the premium brought by the BRT system to the value of properties around the system. An increase of the value of properties around the system implies that more development is likely to occur around the system, thus TOD is likely occurring around the system. The other commonly practiced approach is to evaluate the influence of a BRT system on transit ridership around the system. This approach suggests evaluating the increase of total passenger, passengers per vehicle-trip kilometer (PVK), passengers per route kilometer (PRK) and passengers per hour per direction (PPHPD) figures of buses operating as part of the BRT system. An increase in the figures implies that the use of the BRT system is getting more significance in the area around the system. Thus TOD is assumed occurring around the system. Both approaches are relevant to TOD goals and principles (Prayogi, 2018).

A variant of the second approach is to evaluate the passenger's modal shift triggered by the operation of a BRT system (Suzuki et al., 2013). This approach suggests evaluating the number of BRT system passengers who previously used to drive their vehicles for the same kind of trip. A significant figure of passengers experiencing such modal shift implies that the BRT system is getting more significance in the area around the system. Thus TOD is assumed occurring around the system. While this approach is relevant to TOD goals and principles, it has not been commonly taken yet (Suzuki et al., 2013). Only several researchers are currently taken this approach (Ernst, 2006; Currie & Delbosc, 2011; Currie & Delbosc, 2014).

Carrying out the BRT passengers modal shift evaluation opens up the possibility of understanding the modal shift better. Carrying out the evaluation, one of which, opens up the possibility of understanding the passengers' considerations that are related to their modal shift. Understanding the passengers' modal shift considerations will be a worthy addition to the understanding of how a BRT system may trigger TOD around the system. Furthermore, the understanding will be beneficial for the process of planning and designing BRT systems that may trigger TOD around the systems.

This article reviews some issues that are potentially relevant to BRT system passengers' modal shift considerations. Potential considerations need to be explored before carrying out the passenger's modal shift evaluation so that the evaluation can be carried out appropriately. They need to be explored beforehand, two of which, so that the evaluation can be designed relevant to the TOD goals and principles and beneficial for the process of planning and designing BRT systems that may trigger TOD around the systems.

2. METHODS

This research intends to answer the following question, "What are the issues that are potentially considered by BRT system passengers when they shift their mode of transport?" This article intends to provide a knowledge base for the evaluation of BRT system passengers modal shift so that the result of such evaluation will be able to help explaining how a BRT system may influence urban development around the system and how a BRT system can be appropriately planned and designed to trigger TOD around the system.

This research utilizes one working hypothesis, that is the experience in taking the BRT system is the most significant factor that influences BRT system passengers to shift their mode of transport. The series of perceptions created by the BRT system passengers before, during and after taking the system is the most significant factor that influences the passengers to shift their mode of transport. This hypothesis was developed by considering Ma & Cao (2017) work which concluded that objective built environment affects travel behavior through its influence on human's perception. They found that the mentioned phenomenon applies to transit

passengers. This hypothesis was also aligned with Pandit & Das (2013) idea of planning and delivering transit systems that fit with the potential passengers' expected experience of the transit systems.

The literature review is chosen as the method for this research. It is chosen since it is considered appropriate for revealing the state of the art of the issues mentioned in the research question. By considering the research question and the research-working hypothesis, the literature review is initially directed on three topics, that are the BRT ridership-influencing factors, the BRT system passengers' behavior and the built environment condition around BRT systems. Following the review on the mentioned topics, another literature review was carried out directed on two topics, that are the types of transit system passengers and the types of trip carried out utilizing a transit system.

4. RESULTS AND DISCUSSION

4.1. Passengers' Perception of Bus Rapid Transit (BRT) System's Service

An extensive body of knowledge has shown that the passengers' perception on the transit system's service is related to their preference of taking the system. We may even conclude that the transit system's service is the first thing that is concerned by researchers when trying to understand the patronage and passengers loyalty of a transit system (Sharaby & Shiftan, 2012; Hensher & Li, 2012; Batty et al., 2015; Chakrabarti & Giuliano, 2015; Van Lierop & El-Geneidy, 2016; Satiennam et al., 2016; Chakrabarti, 2017; Fearnley et al., 2017). The passengers' perception of the rapid transit system's service encompasses both quantifiable and less-quantifiable components. Quantifiable components include bus speed, frequency, and headway, while less-quantifiable components include fare competitiveness and affordability, transit network integration, information clarity, comfort and convenience, safety and security.

Vehicle speed, frequency and headway are concerned when trying to understand the patronage and passengers' loyalty of various transit systems (Currie & Delbosc, 2011; Hensher & Li, 2012; Batty et al., 2015; Chakrabarti & Giuliano, 2015; Van Lierop & El-Geneidy, 2016; Satiennam et al., 2016; Chakrabarti, 2017). Vehicle speed, frequency, and headway influence passengers' total trip time. When shifting from driving their vehicle to taking a transit system for the same kind of trip, passengers tend to compare the total trip time of the two means. Passengers also pay specific concern to vehicle frequency and headway as part of perceiving the transit system's unsurpassed reliability. Passengers perceive whether they can rely on taking the transit system at any time or only at certain times. Vehicle headway that is perceived reliable by passengers differs by researches; it generally ranges from 1 to 15 minutes. Currie and Delbosc (2014) found that in the context of Australasian BRT systems, higher bus speed, higher bus frequency, and lower bus headway are in line with higher patronage of the systems.

Fare competitiveness and affordability are concerned when trying to understand the passenger's loyalty and modal-shifting potential of various transit systems (Sharaby & Shiftan, 2012; Hensher & Li, 2012; Batty et al., 2014; Satiennam et al., 2016; Fearnley et al., 2017). Along the time, passengers tend to keep comparing the cost of taking the transit system with the cost of traveling by other means of transport (including driving personal vehicle) for the same kind of trip. Passengers also often evaluate the worthiness of the fare paid for a transit system with the system's reliability (vehicle speed, frequency, and headway). Some passengers also evaluate the cost of taking transit with their income. Any finding cannot be found from the mentioned works in regards to the one-fitting-all fare formula, of the fare that is commonly perceived appropriate by transit passengers.

Furthermore, Sharaby & Shiftan (2012) pointed out that passengers pay attention more to the total cost of taking transit than to the pre-trip fares. They noted that in the context of Haifa

transit systems, passengers take multiple transit systems one after another for a single trip. Consequently, passengers pay attention to the total fare for taking the transit system of all legs than the fare of each leg. Sharaby & Shiftan (2012) argued that the implementation of five-zone fare system with free transfer and generally reduced fare in Haifa would attract people to take transit more.

Transit network integration is concerned when evaluating patronage and modal-shifting potential of various transit systems (Sharaby & Shiftan, 2012; Hensher & Li, 2012; Batty et al., 2015; Chakrabarti, 2017). Transit network integration necessitates the availability of comprehensive coverage of the transit system. Hensher & Li (2012) found that network width correlates positively with passengers per route kilometer (PRK) figure. Transit network integration encompasses physical infrastructure integration, network-wide reliability (vehicle speed, frequency, and headway) standardization, and network-wide fare standardization and integration. Batty et al. (2015) and Chakrabarti (2017) found that the experience when transferring between modes of transit as a significant modal-shift consideration. Batty et al. (2015) and Van Lierop and El-Geneidy (2016) argued that the information clarity of a transit system, especially if the system is part of an extensive transit network, strongly correlates with the system's patronage and passengers' loyalty.

Comfort, convenience, safety, and security are concerned when evaluating patronage, passengers loyalty and modal-shifting potential of various transit systems (Currie & Delbosc, 2011; Hensher & Li, 2012; Batty et al., 2015; Van Lierop & El-Geneidy, 2016). The qualities are experienced and paid attention by passengers both while on board (inside the vehicle) and off-board (outside the vehicle, e.g., waiting for the vehicle and transferring between vehicles).

We may conclude from this sub-section that the bus rapid transit (BRT) system passengers' perception on the BRT system's service is the passengers' potential consideration when they shift their modes of transport from driving their vehicles to taking the BRT system. The system's service includes the bus speed, frequency, and headway, fare competitiveness and affordability, transit network integration, information clarity, comfort and convenience, safety and security. Table 1 briefly summarises passengers' perception on components of the transit system's service that are related to their preference of taking the system based on the reviewed researches.

Table 1 Passengers' perception of components of the transit system's service related to passengers' preference for taking the system

	Passengers' perception of:			
Current research findings by:	Vehicle speed, frequency, and headway	Fare competitiveness and affordability	Transit network integration	Comfort, convenience, safety, and security
Batty et al. (2015)	V	V	V	V
Chakrabarti (2017)	V		V	
Chakrabarti & Giuliano (2015)	V			
Currie & Delbosc (2011)	V			V
Currie & Delbosc (2014)	V			V

	Passengers' perception of:			
Current research findings by:	Vehicle speed, frequency, and headway	Fare competitiveness and affordability	Transit network integration	Comfort, convenience, safety, and security
Fearnley et al. (2017)		V		
Hensher & Li (2012)	V	V	V	V
Satiennam et al. (2016)	V	V		
Sharaby & Shiftan (2012)		V	V	
Van Lierop & El-Geneidy (2016)	V			V

4.2. Passengers' Perception of the Built Environment around the Bus Rapid Transit (BRT) System

A number of researchers found that the condition of built environment around various transit systems is related to the systems' patronage and modal share (Estupinan & Rodriguez, 2008; Mohanty et al., 2017; Ramezani et al., 2017; García-Palomares et al., 2018; Li et al., 2018; Ramezani et al., 2018). It can be assumed from their works that the transit systems' passengers perceive the built environment around the transit systems. Following Ma and Cao (2017) work, the perception is assumed influencing the passengers' preference of taking the transit systems.

Table 2 Passengers' perception of components of the built environment around the BRT system related to passengers' preference of taking the system

	Passengers' perception of:		
Current research findings by:	Street network design around the transit stops	Availability of access to certain places to and from transit stops	Walkability and cycle ability of streets around the transit stops
Estupinan and Rodriguez (2008)			V
Garcial-Palomares, et al. (2018)	V		
Li et al. (2018)		V	
Mohanty, et al. (2017)			V
Ramezani, et al. (2017)			V
Ramezani, et al. (2018)	V		

The mentioned researchers found that the street design around transit stops is strongly related to the patronage and modal-share of various transit systems. Garcia-Palomares et al. (2018) and Ramezani et al. (2018) paid attention to the street network design around the transit stops. They

found the significant relation between transit stops' integration with the urban street network and the patronage and modal-share of the transit system. Similarly, Li et al. (2018) found that the availability of access to certain places to and from transit stops is significantly related to the transit system modal-share. Garcia-Palomares et al. (2018) argued that in the context of Madrid, a transit stop-oriented street network is strongly related to the higher usage demand of the transit system. Furthermore, Estupinan and Rodriguez (2008), Mohanty et al. (2017) and Ramezani et al. (2017) found that the walkability and cycle ability of streets around the transit related to the transit system modal-share. Table 2 briefly summarises passengers' perception on components of the built environment around the BRT system that are related to their preference of taking the system based on the reviewed researches.

4.3. Passengers' Background

When trying to understand the various transit systems passengers' behaviour and preference, a number of researchers suggested to pay attention to the passengers' background (Chakrabarti, 2017; Satiennam et al., 2016; Shen et al., 2016; Van Lierop & El-Geneidy, 2016; Ramezani et al., 2017; Grise & El-Geneidy, 2018; Newbold & Scott, 2018). Within their researches, they found that passengers' behavior and preference vary through various backgrounds. Passengers' behavior and preference are not homogenous, though the magnitude of the heterogeneity may vary as well. Some researchers went further by classifying transit passengers into some groups and analyzing the behavior and preference of each group's members (Van Lierop & El-Geneidy, 2016; Grise & El-Geneidy, 2018; Newbold & Scott, 2018).

Three most recurring issues that differ passengers' behaviour and preference are their income, ownership of personal vehicle and ownership of driving license (Chakrabarti, 2017; Satiennam et al., 2016; Shen et al., 2016; Van Lierop & El-Geneidy, 2016; Grise & El-Geneidy, 2018; Li et al., 2018). There is a relatively consistent finding that one's income, ownership of personal vehicle and ownership of driving license correlates negatively with his/her preference of taking transit. Supplementary to this finding, Shen et al. (2016) found that in the case of Shanghai citizens, one's job status correlates negatively with his/her preference of taking transit. Within the context of Montreal and Vancouver citizens, Van Lierop & El-Geneidy (2016) concluded that there are three groups of transit system passengers, that are captive riders (users who are dependent on transit), choice riders (car owners who choose to take transit) and captive-by-choice riders (users who are dependent on transit but could own a car). Each group have distinct background and preference for taking transit.

Newbolt & Scott (2018) and Satiennam et al. (2016) found that one's age may influence his/her preference on taking transit. Furthermore, in the case of Canadian citizens, Newbolt and Scott (2018) noted that the preference is relatively attached to the age cohort and not changed by the development of a life stage. They found that Millennials (individuals born following Generation X and between the early 1980s and early 2000s) have transit-taking preference distinct to the preceding and following generations. They found that the preference does not change much as the Millennials grow older.

We may conclude from this sub-section that passengers' behavior and preference are not homogeneous among all passengers. Passengers' behavior and preference may vary through various backgrounds, including income, ownership of the personal vehicle, ownership of the driving license, age and age cohort. Table 3 briefly summarises components of passengers' background that may create heterogeneity among passengers' behavior and preference based on the reviewed researches.

Table 3 Components of passengers' background that may create heterogeneity among passengers' behavior and preference

	Passengers' background:	
Current research findings by:	Income, ownership of personal vehicle and ownership of a driving license	Age
Chakrabarti, 2017	V	
Grise & El-Geneidy, 2018	V	
Li et al., 2018	V	
Newbold & Scott, 2018		V (Age cohort)
Satiennam et al., 2016	V	V
Shen et al., 2016	V	
Van Lierop & El-Geneidy, 2016	V	

4.4. Types of Trips

When trying to understand the various transit systems passengers' behaviour and preference, a number of researchers suggested to pay attention to the different kind of trips carried out by the passengers (Chakrabarti & Giuliano, 2015; Fearnley et al., 2017; Ramezani et al., 2017; Ramezani et al., 2018; Soltani & Shams. 2017). The differentiation can be based on the purpose, time and distance of the trip.

Ramezani et al. (2017) and Soltani & Shams (2017) differentiated the trips they analyze by the trip purpose, that are work-related and nonwork-related trips. They did not elaborate one the justification of such differentiation, neither did they elaborate one the definition of each trip. They found that the citizens of Rome, San Fransisco, and Shiraz have a different transit-taking preference for work and non-work trips. For instance, Ramezani et al. (2018) found that the citizens of Rome have a higher transit-taking preference for non-work trips where convenient and walkable street available around the transit stops. Meanwhile, the citizens' transit-taking preference for work trips is not much related to the availability of convenient and walkable street around the transit stops. Fearnley et al. (2017) did a more detailed trip differentiation than the previously mentioned researchers; they differentiated the trips they analyze by the trip purpose into commuting, school, business, grocery, picking up and leisure. Similar to the previously mentioned research finding, Fearnley et al. (2017) found that the citizens of the Greater Oslo have a different transit-taking preference for each trip purpose.

Chakrabarti & Giuliano, (2015) differentiated the trips they analyze by the trip time, that are the weekday peak times and off-peak times trips. They defined weekday peak times as Monday to Friday 6-9 AM and 3-7 PM and off-peak times as all other times outside the weekday peak times. They found that the Los Angeles Metro passengers have different perception and behavior regarding the transit network's reliability during the weekday peak times and off-peak times. Fearnley et al. (2017) also differentiated the trips they analyze by the trip distance, that are 0-2km, 2-5km, 5-10km, 10-25km and over 25km. Fearnley et al. (2017) found that the citizens of the Greater Oslo have a different transit-taking preference for each trip distance group.

We may conclude from this sub-section that passengers' behavior and preference may also differ by their types of trips. The trips may be differed by the purpose, time and distance of the trip. Table 4 briefly summarises components of types of the trip that may create heterogeneity among passengers' behavior and preference based on the reviewed researches.

Table 4 Components of types of the trip that may create heterogeneity among passengers' behavior and preference

	Types of the trip:		
Current research findings by:	Trip purpose	Trip time	Trip distance
Chakrabarti & Giuliano, (2015)		Peak times (Monday to Friday 6-9 AM and 3-7 PM) and off-peak times (all other times outside the peak times)	
Fearnley et al. (2017)	Commuting, school, business, grocery, picking up and leisure		0-2km, 2-5km, 5-10km, 10-25km and over 25km
Ramezani et al., 2017	Work-related and non work-related		
Ramezani et al., 2018	Work-related and non work-related		
Soltani & Shams. 2017	Work-related and non work-related		

5. CONCLUSION

there are some issues potentially considered by passengers when shifting their mode of transport from driving their own personal vehicle to taking a bus rapid transit (BRT) system, that are the system's bus speed, frequency and headway, fare competitiveness and affordability, transit network integration, information clarity, comfort and convenience, safety and security. We also may conclude from sub-section 'Passengers' Perception on the Built Environment around the Bus Rapid Transit (BRT) System' that there are some other issues potentially considered, that are the street network design and street design around the BRT stops. These issues are the main things that need to be evaluated through passengers' interview in order to better understand how a BRT system may influence urban development around the system and how a BRT system can be properly planned and designed to trigger transit-oriented development (TOD) around the system. Evaluating throughan interview is appropriate for understanding the passengers' perception, in which understanding the passengers' perception is suggested by Ma & Cao (2017). Carrying out a revealed-preference (RP) interview to BRT system passengers will be appropriate for the matter.

Furthermore, we may infer from the discussions on sub-sections ‘Passengers' Background' and ‘Types of Trips' that the result of suchan interview may presumably be not homogenous among all passenger-trips. We may infer from the discussion on sub-section ‘Passengers' Background' that the interview result may presumably beheterogeneouss among all passenger-trips due to the different backgrounds of the passenger-interviewees. We may also infer from the discussion on sub-section ‘Types of Trips' that the interview result may presumably beheterogeneouss due to the different types of trips carried out by the passengers. These potential heterogeneities need to be paid attention t, so that the result of the modal-shift interview is not mistakenly considered homogeneous among all passenger-trips. At the very least, the interview needs to beadequatelyy carried out so that itdoes nott only cover passengers of aspecificn background or aparticularn type of trip.

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